Lepidoptera
EPSM
2219
R06
2718

4500
FS-PNW-2202

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE

Progress Report

BIOLOGY AND BEHAVIOR OF THE EUROPEAN PINE SHOOT MOTH IN WESTERN WASHINGTON, 1964

by

W. K. Coulter, Research Entomologist

Division of Forest Insect Research
Pacific Northwest Forest and Range Experiment Station
Portland, Oregon
May, 1965

This report is not for publication in whole or in part without prior approval of the Chief of this Bureau.

REFERENCE LIBRARY-TM

C O N T E N T S

	Page
INTRODUCTION	1
OBJECTIVES FOR 1964	2
METHODS	2
RESULTS	5
Biology and Behavior	5
Adult emergence	5
Flight	7
Sex attraction	7
Mating	9
Oviposition and incubation	9
Fecundity	11
Longevity	11
Laboratory Rearing Techniques	12
Adult rearing	12
Egg rearing	15
Insect Parasites and Predators	16
Associated Insects	16
SUMMARY	17
LITERATURE CITED	18

LIST OF FIGURES AND TABLES

Figures

1. Oviposition cage constructed from one-quart ice cream container lined with black cloth 4

Tables

1. The daily production of shoot moth adults reared in the laboratory in three types of cages, Bellevue, Wash., 1964 6

2. Rate of oviposition by shoot moth collected during mating in the field and caged with foliage in the laboratory at Bellevue, Wash., 1964 10

C O N T E N T S (Cont'd.)

Page

Tables

3. Diurnal emergence of shoot moth adults in laboratory rearings, Bellevue, Wash., 1964 13

4. Sex ratio of adult shoot moth emerging in the laboratory at different times of day, during two periods, July 1-3, and July 6-13, 1964, Bellevue, Wash. 14

5. Egg production by shoot moth collected during mating in the field and caged in the laboratory with a food supply, Bellevue, Wash., 1964 15

BIOLOGY AND BEHAVIOR OF THE EUROPEAN PINE SHOOT MOTH IN WESTERN WASHINGTON, 1964

by

W. K. Coulter, Research Entomologist [1/]

INTRODUCTION

The European pine shoot moth, Rhyacionia buoliana (Schiff.) a foreign forest pest, has become established in the Puget Sound area of western Washington. While current infestations are mainly on ornamental pines in residential areas, they threaten to spread to native timber-producing ponderosa pine areas. Experience with this insect indicates that once it becomes established in native ponderosa pine, it will cause serious control problems and economic losses. The only way of preventing this spread is to eradicate the insect throughout western Washington.

None of the standardized direct control methods are feasible for eradicating this insect. A few, small, isolated infestations have been successfully eradicated by destroying the trees or by fumigating them with methyl bromide (Carolin et al. 1962; Klein and Thompson 1962; Carolin and Coulter 1963). [2/] However, the use of these methods to eradicate the overall infestations is neither economically practical nor technically feasible because of the general extent of the infestations and the difficulty of detecting very light insect populations.

The most feasible approach to eradication of this pest is to use one or more of the new natural control techniques. The scheme of these new techniques is to exploit the inherent characteristics of the insect, and by manipulation, alter their biology or behavior so that they destroy themselves. Examples of specific techniques are population attrition through induced sexual sterility, selective attraction, and trapping.

The requirements for successful use of these techniques are as follows:

1. A detailed knowledge of the insect's biology and behavior.

2. Precise survey methods for determining presence or absence of very small insect populations.

3. Efficient laboratory rearing procedures; first for maintaining a supply of insects for test purposes, and second for obtaining large numbers of adults (a feature of the sterile male technique).

1/ Acknowledgment is gratefully made to Mr. Randall W. Smith who assisted in collecting much of the field data.

2/ Names and dates in parenthesis refer to Literature Cited, p. 18.

The general biology and habits of the shoot moth are well known from previous investigations. Because of its spreading destructiveness and economic importance in eastern United States and Canada, it has been the subject of increasing intensive studies. The most intensive biological studies are the recent work of Pointing and Green in southern Ontario. 3/ Their reports have been a main source of reference. Other major references to biology and behavior are cited later in this report.

No information is available on survey methods or laboratory rearing procedures for this insect.

The requirements of the new eradication techniques indicate broad lines of research needs. The 1964 studies in the Puget Sound area explored these general research needs to determine whether the techniques, particularly the sterile male technique, are workable. While the studies were mainly exploratory, some information pertinent to specific problems was recorded in detail and all records are included in this report for reference.

OBJECTIVES FOR 1964

1. Study the insect's biological and behavioral characteristics in the Pacific Northwest, with emphasis on those characteristics which are pertinent to the use of new eradication techniques.

2. Investigate methods of laboratory rearing to obtain adult moths and eggs.

METHODS

Several characteristics of the insect's biology and behavior pertinent to the new eradication techniques were investigated. However, to accomplish this in one season, it was necessary to restrict many investigations to incidental observations which could be compared with results recorded in eastern United States and Canada. Laboratory rearing studies were likewise restricted to small-scale tests of equipment, to determine fundamental procedures, and to obtain experience in manipulating this insect in the laboratory.

A temporary field laboratory was established at Bellevue, Washington, as a base for field studies and to house the rearing studies. Field studies were conducted in a nearby residential area where adult behavior was observed to record flight, sex attraction, and mating. In the field laboratory, adult emergence, oviposition and eclosion were studied.

3/ (Pointing 1961; Green 1962; Green and Pointing 1962; Pointing 1963).

Laboratory rearing studies consisted of two tests; (1) to devise an efficient method for obtaining adults from infested pine shoots, and (2) to devise an efficient method of obtaining eggs to provide a source of larvae.

Mass rearing from infested pine shoots was the method used to obtain a supply of adults. 4/ Three types of mass rearing cages were tested; screen, wooden, and corrugated cardboard. Records of total moth production, condition of moths, and ease of collecting were kept to judge comparative efficiency. The screen cages were 24 by 24 by 33 inches, covered with copper screening, and fitted with a sliding door. The wooden cages were 12 by 12 by 23 inches, lined with heavy waxed paper, and fitted with a clear plastic-covered sliding door. The cardboard cages were 13 by 13 by 24 inches, sealed with marking tape, and fitted with two 4-inch shell vials. Three cages of each type were used. Infested shoots were collected from three residential areas and divided into the nine cages. The shoots were collected on June 24-25 when the first adults began to appear in the field. Adult shoot moths, parasites, and associated insects were removed from the cages at regular intervals. The shoot moths were held for observations on behavior and later a small series from each area was preserved as specimens. Representative specimens of all parasites and associated insects encountered were also preserved.

Rearing studies to obtain supplies of eggs, tested egg production when the adults are provided with food. Some copulating pairs, collected in the field, were caged in one-quart ice cream containers. These cages, shown in Figure 1., were lined with black cloth and perforated to allow air circulation. Three treatments were tested; honey in water, sugar in water, and plain water. Other copulating pairs were isolated in plastic-box cages, without food, to obtain daily records of egg production.

4/ In February 1965, a study was begun at Washington State University to develop methods for mass rearing the shoot moth on artificial media.

Figure 1. Oviposition cage constructed from one-quart ice cream container lined with black cloth.

RESULTS

Biology and Behavior

Adult emergence. The seasonal occurrence of adults was determined from field observations of moth flight. The first adults were seen in mid-June, and the last at the end of July, covering a period of seven weeks. This period is similar to that recorded elsewhere. It commenced about one week earlier than Pointing (1961) reported for seasons of comparable weather in Ontario, and about one week later than Miller and Neiswander (1955) reported for Ohio.

Adult development was recorded by periodic field sampling before emergence, and by daily emergence from laboratory rearings. Summary of these data give the following approximate period and rate of development for 1964:

Date	Total Shoot Moth	Larvae	Pupae	Adults	Basis for Record
		percent			
May 1	13	100	0	0	Field examination
19	18	94	6	0	do.
28	30	83	17	0	do.
June 11	27	33	67	0	do.
18	10	0	100	0	do.
25	1326	3	94	3	Laboratory rearing
July 2	1281	0	39	61	do.
9	501	0	8	92	do.
13	39	0	0	100	do.

Records of adult emergence in the field were restricted to those shown in the table. However, the peak emergence in the laboratory on June 30 (Table 1.) is estimated to be very close to the peak emergence in the field. At any rate the difference is not great--no greater than seasonal variation recorded in other studies in the East.

Comparison of sex ratios during pupal development and adult emergence shows a pattern similar to that reported by Pointing (1961) and others. The following summary shows that males emerge ahead of the females:

Collection Dates	Stage of development	Males	Females	Sex Ratio
June 11-19	Early adult emergence	17	11	1.5:1.0
July 1-7	Peak of adult emergence	160	186	1.0:1.2
July 8-17	Late adult emergence	45	97	1.0:2.1

Table 1.--The daily production of shoot moth adults reared in the laboratory in three types of cages, Bellevue, Wash., 1964

Cage type	Number of moths																						
	June							July															Total
	24	25	26	27	28	29	30	1	2	3	4	5	6	7	8	9	10	11	12	13			
Screen	0	15	14	32	26	41	57	49	41	27	33	38	32	25	24	17	10	2	2	0			485
Wood	0	18	17	29	58	50	60	58	36	25	28	39	23	11	10	2	2	1	0	2			469
Cardboard	2	10	5	16	13	32	48	53	45	16	11	16	19	33	14	19	9	6	4	1			372
Total	2	43	36	77	97	123	165	160	122	68	72	93	74	69	48	38	21	9	6	3			1326

Flight. Observations on the behavior of the shoot moth in flight indicates it is similar to that reported in Ontario by Green (1962) and Green and Pointing (1962). Spontaneous flight begins about two hours before sunset, reaches a peak intensity between sunset and darkness, and ceases at complete darkness. The most conspicuous flight activity is a wandering, directionless, fluttering over the foliage. This is believed to be mainly a male flight characteristic--males searching for females. In contrast, the female flight pattern was a more direct darting from tree to tree or darting out of sight. The latter was seldom seen.

Moths are often disturbed into flight. This behavior is particularly noticeable during the times preceeding and following the normal daily flight period. Movements by observers, other insects, or a gust of wind frequently cause flight during the daytime. A strong beam of light has the same effect at dusk.

The physical factors affecting flight were noted. During the period of observations, temperatures ranged from 45 to 70 degrees F. All observations confirmed the experimental evidence recorded by Green (1962). Light intensity and temperature are the main controlling factors. They act independently, flight occurring only when both are favorable. Strong winds and heavy rains were noted to limit flight, but their effects, independent of temperature, are not known.

The adults were occasionally confused with lawn moths, Crambus sp., which have flight habits similar to the shoot moth.

Sex attraction. Pointing (1962) reported the virgin female releases a scent which attracts the males for mating. Observations at Bellevue, Washington, revealed a similar characteristic.

The method of observation was as follows: During the eight-day period of June 30 to July 7, when adult emergence was at its peak, supposedly virgin females from mass rearing cages were placed in containers around heavily infested mugho pine. 5/ Continuous observations were made while males were in flight between sunset and darkness. Nine females were isolated in containers constructed by boring a 3/4-inch hole in a 3 by 6 inch block of one inch Douglas-fir lumber. Groups of females of various ages were caged in 1 by 2 by 3 inch paper boxes for similar observation.

The results, as already indicated, showed that the female releases a chemical sex attractant. Attraction occurred when the female could not be seen by the male, eliminating the possibility of visual orientation as a primary means of attraction. Auditory attraction was later eliminated when males were observed to search for over ten minutes the exact place where mating had just previously occurred.

5/ It was later discovered that some mating occurred in the rearing cages. Therefore some of the females used in these observations may not have been virgin.

Other observations of attraction are worth noting. Seven of the nine moths isolated attracted males sometime during the eight days of observation. There was no definite pattern; one moth, attractive on the first day was still attractive on the seventh day; two moths were attractive on the first day; and five were attractive on the seventh day. All three groups of different ages (24 newly emerged, 24 several days old, and 24 dead) were attractive with no apparent difference in the distance of their effectiveness. However, the new and old attracted males sooner and in greater numbers than did the dead moths.

Weather factors, which affect flight, appear to also affect attraction. These factors were recorded as follows:

Date	Weather	Attractive	Not attractive
June 30	Clear, warm, calm	1	6
July 1	Overcast with rain, warm, wind 15 mph.	2	7
" 2	Overcast, cool, calm	0	9
" 3	-	-	-
" 4	-	-	-
" 5	Overcast, warm, wind 5 mph.	3	6
" 6	Overcast, warm, wind 5 mph.	5	4
" 7	Overcast with rain, cool, wind 20 mph.	1	8

The weather was variable during the eight-day period, and the apparent optimum conditions for attraction did not occur until July 5. On June 30, when weather conditions appear to be satisfactory and many moths were active, the temperature dropped at the time when the light intensity was favorable for attraction. (Later, on July 11 and 12, natural attraction and mating was common when the same general weather conditions occurred except the temperature remained higher until well after darkness.) On July 1, attraction began about two hours before sunset, but one hour later a heavy rain began and all flight ceased. One male, attracted to an isolated female before the heavy rain began, continued to flutter around her container. On July 2, a relatively cool evening, many moths were in flight but no attraction occurred. On July 5, attraction occurred continuously from 2 hours and 45 minutes before sunset until total darkness, a total of nearly four hours. Unfortunately, observations were not begun on July 6 until late in the evening. On July 7, a wind and rain storm occurred before sunset which limited attraction and flight.

A single female moth was observed to be attracted to another female. On July 11, a pair of moths were seen beginning to mate on the foliage of an ornamental pine. The pair were removed from the foliage after five minutes, and almost immediately three moths were attracted to the mating site. All were collected and their sex determined in the laboratory. Two were males and one was a female.

Mating. Mating in the field was observed from June 30 to July 22, but was actually recorded on only six of the days during this three week period. On these six days, 20 pairs were seen of which 18 were collected for laboratory rearings. All 20 pairs began mating between sunset and 30 minutes after darkness, a period of 1-1/2 hours. No mating was seen on July 5 or 6, the days previously reported when attraction of males to isolated females was intense and extended from early evening until nearly darkness, a period of four hours.

Attempts to manipulate and control mating in the laboratory failed. Fertile eggs were obtained in one small series of tests, but the mating was not seen and may have occurred before the test moths were isolated. In other tests no mating was seen and no fertile eggs were produced.

Oviposition and incubation. The characteristics of egg production of the shoot moth was investigated in the laboratory. Field studies were not made, nor was the actual egg laying observed. The latter has been described in detail by Pointing (1961).

The egg production of the female throughout her period of oviposition was based on 18 females caged on 6-inch twigs of lodgepole pine in ventilated plastic boxes 6x2 - 1/4x1 - 1/4 inches. Each female was transferred daily to a fresh twig and cage until a majority of her eggs were laid. Males from each pair were also caged to determine their longevity after mating. Neither males nor females were mated again after they were caged in the laboratory.

Table 2 shows the daily distribution ofeggs laid by each female. The length of the oviposition period averaged 12.4 days, but was variable ranging up to four weeks. However, the daily totals of all females show most eggs are laid on the first day and progressively lesser numbers laid each day thereafter. A comparison of the eggs deposited by the first mated females and those mated nearly two weeks later shows no difference in total egg production or egg mortality.

The incubation period in laboratory cages was 11.5 days with a range of 9 to 13 days. The eggs of 13 females fell within the range of 10 to 12 days. These figures are higher than those obtained in the East; Miller and Neiswander (1955) 9 days (range 8-10), Friend and West (1933) 10.3 days (range 9-12), and Pointing (1963) 10.8 days (range 8-14). This may have been the result of lower temperatures in the laboratory at Bellevue, Wash. as the incubation occurred in a shaded, unheated part of the laboratory.

Table 2.--Rate of oviposition by shoot moth collected during mating in the field and caged with foliage in the laboratory at Bellevue, Wash., 1964.

Mated pair	Date of mating	Oviposition period	Days after mating: 1	2	3	4-9	10	11	12 or more	Total	Mortality 1/
		-- days --									--percent --
A	6/30	8	4	14	2	2	-	-	-	22	0
B	6/30	13	50	37	41	30	13	5	23	199	23
C	7/5	21	52	-	22	3	0	0	29	106	37
D	7/10	2/	-	-	-	-	-	-	-	-	-
E	7/11	16	52	16	12	35	4	3	9	131	21
F	7/11	28	12	24	0	5	4	2	76	123	41
G	7/11	5	45	9	6	31	-	-	-	91	8
H	7/11	5	11	6	4	24	-	-	-	45	13
I	7/12	4	15	11	0	13	-	-	-	39	0
J	7/12	3	9	7	2	-	-	-	-	18	6
K	7/12	19	0	9	3	2	1	1	8	24	38
L	7/12	16	71	19	12	19	6	2	15	144	15
M	7/12	4	11	30	0	15	-	-	-	56	29
N	7/12	24	67	19	23	39	3	2	30	183	10
O	7/12	10	13	0	46	36	7	-	-	102	22
P	7/12	11	78	11	0	22	0	3	-	114	4
Q	7/12	4	55	22	3	33	-	-	-	113	2
R	7/12	19	59	12	22	38	12	6	31	180	12
Totals		12.4	604	246	198	347	50	24	221	1690	
			Percent								
			36	14	12	21	3	1	13		17.4

1/ Egg mortality includes sterile eggs and fertile eggs that did not hatch.

2/ Female killed by spider on July 11, before oviposition began.

Fecundity. The fecundity of the female shoot moth caged in the laboratory was determined by two methods -- the one mentioned above, and a second method which was used primarily to test egg production when food is supplied the adult moth during oviposition. The details of the latter method will be discussed later in this report under the section on mass rearing. The main differences between the two procedures, other than the source of food, was that in the second method the mated male and female were caged together; they were not handled during the oviposition period; and the cage, a cardboard one-quart ice cream container, was more than three times the volume of the plastic box used in the first method. The fecundity of the shoot moth by both methods is as follows:

Cage type	Number of females	Number of eggs	Eggs per female	Egg mortality
				--percent--
Plastic box	17	1690	99	17
Cardboard container	6	662	110	15

The average number of eggs per female produced by each method is less than the six-year average of 115.7 from 149 females obtained by Pointing (1961). Miller and Neiswander (1955) obtained a much higher average of 168 eggs per female, but this was based on the production of six females. It is interesting to note that Miller and Neiswander found a 15 percent egg mortality in insectary rearings. Pointing did not report on egg mortality, considering it of little consequence because, "sterile eggs were rarely seen in the field".

Longevity. Females collected while mating in the field lived an average of 17 days caged on foliage in the laboratory. A single female lived 30 days after laying eggs nearly every day for 28 days. The total average longevity for females caged in the laboratory is about 18 days since all previously cited studies report mating usually occurs within 24 hours after female emergence. This longevity is only tentative since it is based on two assumptions: (1) that female emergence behavior in the Northwest is typical, and (2) that females mate only once.

Males collected with the females and isolated in the same manner lived an average of 15 days with a maximum of about 20 days. These data are probably not meaningful in terms of longevity since the males may have been in flight for several days and have mated previously. Pointing (1961) suggests that the excess of females toward the end of the emergence period requires some males to mate more than once. Furthermore, Pointing's tests showed that males may successfully mate as many as four times with virgin females. Therefore, we may conclude that in the laboratory the longevity of the average male is somewhat more than 15 days.

Laboratory Rearing Techniques

Adult rearing. Tests with three types of cages; screen, wooden, and corrugated cardboard showed little difference in the number of adult shoot moth produced.

Cage type	Number shoots	Number moths	Moths per shoot
Screen	849	485	.57
Wooden	869	469	.54
Cardboard	875	372	.43

The main difference in rearing environment provided by the cages was a higher humidity in the wooden cages. It is concluded from these tests that if shoots are cut when pupation is complete and reared at room temperatures, cage humidity will not affect moth production.

The number of moths produced by host pine species was not tested. However, when individual cage records are combined by locality of collection, the tabulation shows little difference in numbers produced. These records are as follows:

Locality	Host	Number shoots	Number moths	Moths per shoot
Bellevue	Mugho	900	453	.50
Sandpoint	Mugho Lodgepole	981	451	.46
Mercer Island	Scots Austrian	712	422	.59

There was a difference in the efficiency with which the moths could be collected from the cages. Moths could be collected most quickly from the cardboard cages since they were confined to the collecting vials attached to the cages. (Moths were collected from the screen and wooden cages by teasing each moth into a shell vial.) However, it was necessary to remove the moths from the cardboard-cage collection vials no less than four times per day to insure their good condition. Moths removed twice a day, at 12-hour intervals, were damaged and appeared less vigorous than those collected in the other types of cages.

Moths were more easily captured in the wooden cages than in the screen cages. Since the main difference between these cages was the humidity within the cages, it is assumed the higher humidity caused the moths to be less active. However, it is further assumed that if a powered, vacuum aspirator had been used, there would have been no difference in efficiency between these cages.

Emerging moths were collected five times a day for eight consecutive days during the peak emergence. Following this period, moths were collected twice daily for eleven consecutive days. Table 3 shows a diurnal emergence pattern, with twice as many moths produced from noon to 8 p.m. as during the remaining hours. Moth production reached a peak at 4 p.m. for the screen and cardboard cages which is similar to the results reported by Pointing (1961). These rearings were conducted under average laboratory conditions of light and temperature and no attempt was made to simulate natural field conditions. Therefore, it is not known whether or not the insect's circadian rhythm was upset. (Pointing reported a peak emergence in the early morning for moths emerging in the field at Ontario.) Neither is it known whether these laboratory reared moths were of normal development and vigor.

Table 3.--Diurnal emergence of shoot moth adults in laboratory rearings, Bellevue, Wash., 1964

Cage type	June 25 - July 2					July 3 - 13		Total
	8 a.m.	12 n.	4 p.m.	8 p.m.	12 m.	8 a.m.	8 p.m.	
Screen	49	63	64	52	37	95	115	475
Wooden	86	77	59	60	38	55	88	463
Cardboard	19	39	51	48	18	47	101	323
Total	154	179	174	160	93	197	304	1261

The sex ratio of adults emerging in the laboratory at different times of day varied little (Table 4). During the period of peak emergence, July 1 to 3, when the average ratio was 1:1, a large difference was found only at midnight. However, even if these data for the midnight collections are typical, they are of little consequence because of the small numbers of moths produced. One week later during July 6 to 13, when the average ratio was one male to 1.7 females, the proportion of females during the 8 a.m. collection was slightly greater than during the 8 p.m. collections.

Table 4.--Sex ratio of adult shoot moth emerging in the laboratory at different times of day, during two periods, July 1-3, and July 6-13, 1964, Bellevue, Wash.

	Collection times during July 1-3								Collection times during July 6-13		
	Total	12 m.	8 a.m.	Subtotal	12 n.	4 p.m.	8 p.m.	Subtotal	Total	8 a.m.	8 p.m.
Males	116	2	49	51	29	17	19	65	86	34	52
Females	119	6	44	50	35	20	14	69	149	64	85
Sex ratio	1:1.0	1:3.0	1:0.9	1:1.0	1:1.2	1:1.2	1:0:7	1:1.0	1:1.7	1:1.9	1:1.6

Egg rearing. Small scale tests to investigate methods for obtaining eggs in the laboratory indicated that more eggs are produced when mated adults are provided with a food of honey and water. When copulating pairs were isolated in cages constructed from one-quart ice cream containers, three pairs fed honey and water averaged over twice as many eggs as three pairs fed sugar and water (Table 5.).

Since many investigators had reported the shoot moth will lay its eggs indiscriminately on practically any surface, even when the foliage of its preferred hosts is provided (Friend and West 1933), the test cages were lined with a black cotton cloth to provide a shaded environment, and also to facilitate handling the nearly opaque colored eggs. The cloth material used (Veriform crisp shape liner) was stiff enough to hold its shape when formed into a cylindrical liner for the ice cream container. One end of the cages was covered with a transparent plastic material for observation of moth feeding. The cages were placed on their sides in the laboratory. The food solution was placed on a one inch square of cotton which was stapled to a two inch square of cardboard cut from the container.

About one-half of the eggs were deposited singly, and one-half in small masses of five eggs or less. Most of the eggs were deposited on the sides of the containers with about nine percent on the plastic covered end and 16 percent on the cloth covered end. Insignificant numbers were deposited on the cotton and cardboard squares.

Table 5.--Egg production by shoot moth collected during mating in the field and caged in the laboratory with a food supply, Bellevue, Wash., 1964

Cage	Food	Number of pairs	Number of eggs	Egg mortality
				-- percent --
A	Sugar-water	1	53	23
C	Sugar-water	1	110	9
G	Sugar-water	1	37	30
	Average		67	16
B	Honey-water	1	132	8
D	Honey-water	1	256	13
F	Honey-water	1	74	27
	Average		154	14
E	Water	1	73	16

The technique allows eggs to be collected efficiently in the laboratory with minimum disturbance to the adults. The trend of oviposition (Table 2) indicates that 83 percent of the eggs are laid within nine days after mating. Since the incubation period is usually ten days or more, most of the eggs will be laid before the first eggs hatch. The liner may be removed at this time to collect the eggs and a replacement liner inserted in the cage.

Insect Parasites and Predators

Mass rearings to obtain adult shoot moth also produced parasites and predaceous insect adults. Although a few other potential hosts were reared, at least two species of parasites and some of the predators undoubtedly developed on the shoot moth.

Two parasites, tentatively identified as Exeristes (Calliephialtes) sp., probably comstocki (Cress.) and Itoplectis quadricingulatus (Prov.), were obtained in significant numbers. Both are native parasites attacking various lepidopterous hosts in the Pacific Northwest. Their total parasitism based on emergence is as follows:

Species	Emergence Number	Emergence Percent	Stage of host killed
Rhyacionia buoliana	1341	94.4	-
Exeristes sp.	28	2.0	Larva
Itoplectis quadricingulatus	47	3.3	Pupa
Other parasites	4	0.3	Unknown
Total	1420		

Predaceous insects reared include six species of Coccinellidae, two species of Syrphidae, one Hemiptera, and one Neuroptera. All have been sent to specialists for identification.

Associated Insects

Mass rearings from pine shoots also produced miscellaneous associated lepidopterous adults. Two moths common in most of the rearing cages were a gelechiid and a tortricid. Four single specimens obtained were a olethreutid and three unknowns. All of these have also been sent to specialists for identification.

SUMMARY

The period of adult shoot moth occurrence on ornamental pines at Bellevue, Washington, in 1964 was seven weeks. The sex ratio when the first adults emerged in mid-June was approximately two males to one female. This ratio changed during the period of occurrence, and near the end of the period the ratio was reversed to two females to one male.

The rate of adult developm ent was as follows: pupation began in mid-May and was completed by mid-June; adult emergence began in mid-June and was completed by mid-July. The peak emergence in the laboratory was on June 30.

Observations of spontaneous moth flight indicated a behavior similar to that reported in detail by Green and Pointing in Ontario. At Bellevue, Wash. moths were frequently disturbed into flight by outside agents associated with the urban locality of the infestation. The effects of these agents on the insect's mating and oviposition are not known.

Field studies showed that female moths possess a chemical sex attractant. There is no evidence of either visual or auditory sex attraction. However, unsuccessful attempts to manipulate mating in the laboratory indicate that other factors may be involved.

Females may be attractive up to seven days or more. The distance at which the chemical attractant is effective is not known. Since males in flight are attracted to the females, factors affecting flight also affect attraction. The consequences of males disturbed into flight are not known.

Mating was readily observed in the field, while attempts to produce mating in the laboratory failed.

The average oviposition period of 17 field-mated females, caged in the laboratory was 12.4 days. The incubation period of 1690 eggs averaged 11.5 days. The average fecundity of these moths was 99 eggs. Six females provided with a food of honey and water or sugar and water averaged 110 eggs.

The longevity of female moths caged in the laboratory averaged 18 days. Male longevity was not determined but is more than 15 days.

Mass rearing tests to produce adults from infested shoots indicated that the type of cage used is of little importance. In these tests all shoots were collected after most of the insects had pupated. Adult emergence in the laboratory was mainly diurnal, and during peak emergence there was no sex difference in this emergence pattern.

Rearing tests to produce eggs from mated pairs provided with a food supply indicated that more eggs are obtained with honey and water than with either sugar and water or water alone. A majority of the total eggs were laid before the first eggs began to hatch. A convenient and efficient oviposition cage was developed.

LITERATURE CITED

Carolin, V. M., and Coulter, W. K.
1963. Eradicating European pine shoot moth in commercial nurseries with methyl bromide. Pac. NW. Forest and Range Expt. Sta. Res. Paper PNW 1, 11 pp.

_____, Klein, W. H., and Thompson, R. M.
1962. Eradicating European pine shoot moth on ornamental pines with methyl bromide. Pac. NW. Forest and Range Expt. Sta. Res. Paper 47, 16 pp., illus.

Friend, Roger B., and West, Allen S. Jr.
1933. The European pine shoot moth (Rhyacionia buoliana Schiff.) with special reference to its occurrence in the Eli Whitney Forest. Yale Univ. School of Forestry Bul. 37, 65 pp., illus.

Green, G. W.
1962. Flight and dispersal of the European pine shoot moth, Rhyacionia buoliana (Schiff.) I. Factors affecting flight, and the flight potential of females. Can. Ent. 94(3):282-299.

_____, and Pointing, P. J.
1962. Flight and dispersal of the European pine shoot moth, Rhyacionia buoliana (Schiff.) II. Natural dispersal of egg-laden females. Can. Ent. 94(3):299-314, illus.

Klein, W. H., and Thompson, R. M.
1962. Procedures and equipment for fumigating European pine shoot moth on ornamental pines. Pac. NW. Forest and Range Expt. Sta. Res. Paper 50, 25 pp., illus.

Miller, William E., and Neiswander, Ralph B.
1955. Biology and control of the European pine shoot moth. Ohio Agr. Expt. Sta. Res. Bul. 760, 31 pp., illus.

Pointing, P. J.
1961. The biology and behavior of the European pine shoot moth, Rhyacionia buoliana (Schiff.), in southern Ontario. I. Adult. Can. Ent. 93(12):1098-1112, illus.

_____
1963. The biology and behavior of the European pine shoot moth Rhyacionia buoliana (Schiff.), in southern Ontario. II. Egg, larva, and pupa. Can. Ent. 95(8):844-863, illus.